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INVESTIGATIONS OF NORMALIZATION TECHNIQUES.(U)
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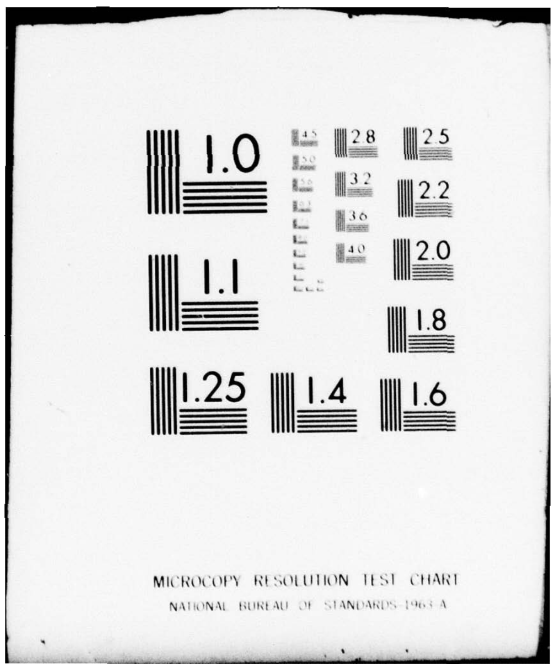
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Contract No. NObsr-95149
Project Serial No. SS041-001, Task 8100
Project Number 002-019-02
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LEVEL II

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TECHNICAL NOTE

INVESTIGATIONS OF NORMALIZATION TECHNIQUES (U)

Prepared for

Commander, Naval Ship Systems Command
Department of the Navy
Washington, D.C. 20360
Attn: Mr. J.D. Hodges
Code 1631

1 April 1966

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Submitted by:

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1. INTRODUCTION

In modern sonar systems one of the large remaining problems is that of obtaining a well-normalized output from the temporal processor without sacrificing processing gain. By a normalized output it is meant that in the absence of signal the output from the processor will possess a stationary statistic, which in turn implies that the mean and standard deviation of the output will be time-invariant. This normalization is required to obtain optimum performance from existing sonar displays due to their limited dynamic range. There are several ways to obtain normalization in the output from the temporal processor. One of these is by the well-known technique of hard-clipping. Unfortunately performance degradations are inherent in this approach. The conventional AGC is another method to achieve normalization. When the AGC is applied before the temporal processor, time constants which are large compared to the signal duration must be used in order not to degrade the signal return. This restriction places a limit on the degree of normalization which may be achieved.

The use of linear matched filter techniques provides an opportunity to do further normalization after the temporal processor. This is due to the time compression of the signal which occurs in such a device. The nominal pulse length from the matched filter is given by the reciprocal of the pulse bandwidth. For example, if 100 Hz bandwidth FM slide signals of ½ sec duration are processed through a linear replica correlator, the pulse length expected in the output is 10 ms. A process similar to AGC may be implemented on this output, but the time constant must now be long relative to 10 ms, instead of ½ sec.

This technical note presents the results of some investigations of techniques for effecting post-correlation normalization. The data used were bottom bounce recordings from the AN/SQS-26, which uses FM slide signals of 0.5 sec duration

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and 100 Hz bandwidth. The processor was a linear replica correlator followed by an envelope detector.

The investigation proceeded in three stages. First, the behavior of the mean and standard deviation of the noise at the output of the processor was examined. Next, normalization was performed using various methods, and the results compared. Finally, the practicability of substituting the geometric mean for the arithmetic mean in the normalization process was examined.

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2. THE UN-NORMALIZED OUTPUT

The mean and standard deviation of the un-normalized correlator output were determined for AN/SQS-26 sea data representing the annulus of bottom bounce transmission with a depression angle of 30°. The data were recorded at the input to the clipper amplifier so that the AGC circuits of the system were used. The data were then passed through a linear correlator and a detector-averager as described above. After breaking the data into sequential 100 ms intervals, a mean value and a standard deviation were calculated for each of these intervals.

The top curve of Fig. 1 shows sequential values of the mean for a typical echo cycle. For this cycle, the mean value of these numbers is 0.042 and the standard deviation of the numbers is 0.014. For a total of 16 echo cycles investigated, the average mean value and standard deviation of the mean value were 0.043 and 0.014, respectively.

The second curve of Fig. 1 shows sequential values of the standard deviations calculated from the 100 ms intervals of the same echo cycle. The mean value for these numbers is 0.017 and the standard deviation is 0.006. The average mean and standard deviation for the 16 echo cycles were 0.018 and 0.007, respectively.

The third curve of Fig. 1 shows the standard deviation divided by the mean. This ratio was calculated for each of the 100 ms intervals described above. The mean value for these numbers is 0.404 and the standard deviation is 0.083. Average values for the 16 echo cycles are 0.411 and 0.093.

When the above measurements were repeated using a 200 ms interval instead of a 100 ms interval, the results given in Table I were obtained.

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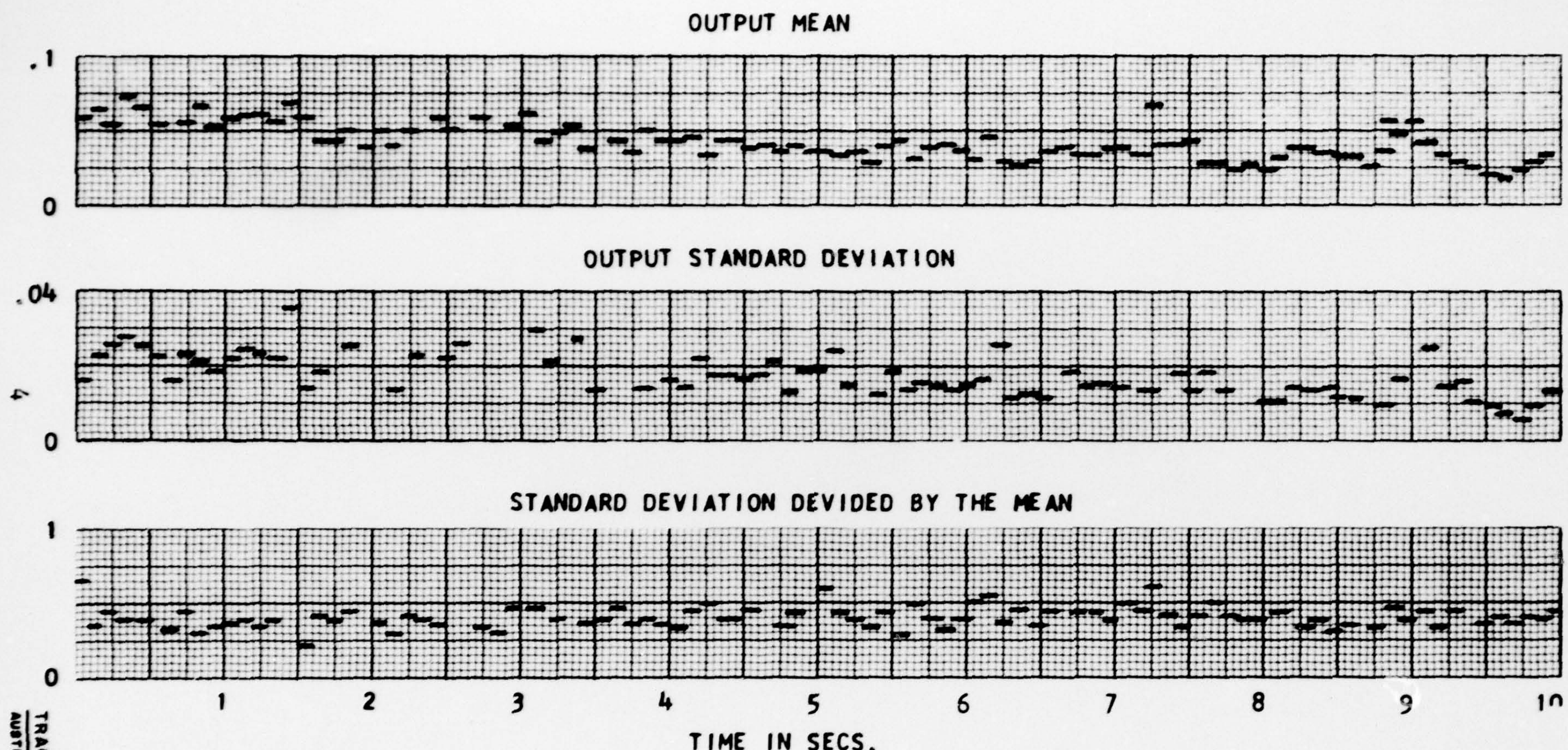

FIG. 1 - MEAN AND STANDARD DEVIATION FOR 100 MS INCREMENTS OF A TYPICAL ECHO CYCLE.

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TABLE I

Data Computed from Sequential 200 ms
Sections from Typical Bottom Bounce Annuli

	For one Typical Echo Cycle	Average for 16 Echo Cycles
Mean Values		
mean	0.042	0.041
standard deviation	0.013	0.012
Standard Deviations		
mean	0.018	0.019
standard deviation	0.006	0.007
Ratio of Standard Deviation to the Mean		
mean	0.426	0.435
standard deviation	0.071	0.078

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3. NORMALIZATION FORMULAS

Normalization was accomplished in three ways according to the following formulas:

$$y = \frac{x-\overline{x}}{\sigma} \,, \tag{1}$$

$$y = \frac{x-\overline{x}}{\overline{x}} \,, \tag{2}$$

$$y = \frac{x}{\overline{x}} \,, \tag{3}$$

where y represents normalized output, x represents input to the normalizer, and σ and $\overline{x}$ are the standard deviation and the mean of the input computed in a region in the vicinity of x. The exact selection of this region is described below.

The data given in the first section carry implications with regard to the three normalization formulas listed. From Fig. 1 it can be seen that both the output mean and the output standard deviation change with time, but that their quotient is approximately time-invariant. Equation (1) will yield an output function which is directly relatable to output signal-to-noise ratio defined by

$$\left(\frac{S}{N}\right)_o = \frac{(P-\overline{x})^2}{\sigma^2} \,,$$

where P is the peak value of the signal plus noise, and should give the closest approximation to an output function having a zero mean and a standard deviation of unity. If the ratio of standard deviation to the mean were time stationary, Eq. (2) would give a result equivalent to Eq. (1) except for a constant factor. The realization of this effect in the following normalization data bears out the observation that this ratio is relatively time-invariant. Furthermore, since Eq. (3), written

in terms of voltage, varies from Eq. (2) only by the additive constant of one, its normalizing effect should be identical to that of Eq. (2). This is also verified in the following data.

For each of the three normalizing equations, two techniques were used to obtain the required values of mean and standard deviation. In the first method, the region of noise from which the mean and standard deviation were calculated consisted of two sections, as shown in Fig. 2. Between the two sections an open window was left wide enough to encompass any signal structure which occurred. The value from the center of this window, represented by x in the normalization formulas, was measured while the mean and standard deviation were computed from the other two sections. The correlator output was then advanced by one point and the process repeated.

The length of each section over which the noise mean and standard deviations were measured was 100 ms. Initially, a center window length of 100 ms was used. This gave erroneous results which indicated a very poor performance for this window structure because, in the data used, the signal structures trailed out beyond the largest peak by more than 50 ms. As a result, some of the signal structure occurred within the second region over which the mean and standard deviation were measured so that excessively large values were measured for these quantities with a resultant decrease in the output peak at the point where the signal occurred. It was necessary to go to a total window length of 200 ms to eliminate this phenomenon. This serves to point out one necessary precaution for using this type of structure: the window must be large enough to include all the structure from the worst expected signals. For a high speed closing target, for example, the window might have to be quite long to avoid actual degradation in system performance due to normalization procedure.

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The second basic technique for obtaining the required values consisted in measuring the mean and standard deviation in a single interval of noise which preceded the sample value x by a given amount δ (Fig. 3). Two different intervals, 100 ms and 200 ms, were used for obtaining the mean and standard deviation of the noise.

Fifty-five echo cycles were selected over which to compare the three normalization schemes. The results are summarized in Table II where Eq. (1), as determined by the two-sided technique, is taken as the reference process. The basis of comparison is the relative peak height of the signal compared to the other peaks in the echo cycle. For example, if for the reference process the signal peak were the second largest peak in the echo cycle and another process resulted in making the signal peak the largest, this latter process would win over the reference process. However, if the signal peak dropped to third position or lower, the process would lose. The table lists the number of echo cycles in which each process performed better than the reference process, the number for which it tied, and the number for which it lost. The average position of the signal in peak height rank is also shown.

In Table II, the first row summarizes the results for all the echo cycles considered. In the second row, results are summarized only for those cycles in which the signal peak was not the largest peak value. As expected, Eqs. (2) and (3) gave equivalent results. Also, it is noted that 100 ms is not really an adequate interval for computing the mean and standard deviation since only 10 independent samples were involved.

Examples of post-correlation normalization may be seen in the outputs for bottom bounce operation shown in Figs. 4 and 5. In these figures, the entire echo cycle was used instead of just the annulus. In Fig. 4, the upper graph shows the un-normalized

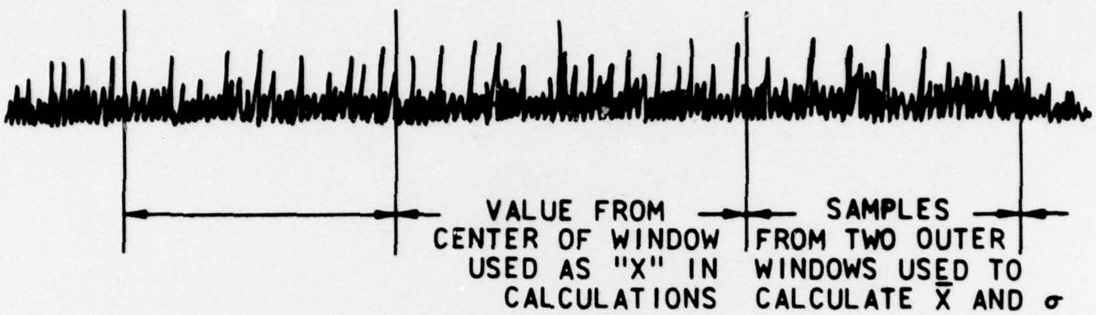

FIG. 2 - FIRST METHOD OF OBTAINING MEAN AND STANDARD DEVIATION

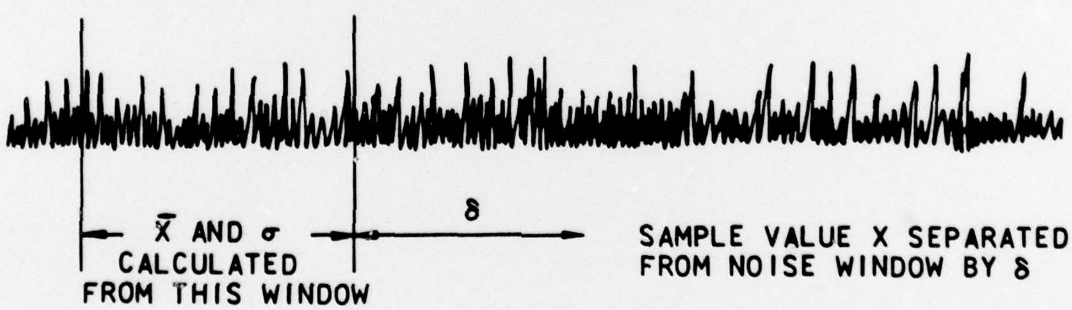

FIG. 3 - SECOND METHOD OF OBTAINING MEAN AND STANDARD DEVIATION

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Table II

	MEAN AND STANDARD DEVIATION COMPUTED IN REGION CONSISTING OF TWO SECTIONS EACH 100 MS LONG, ONE BEFORE AND ONE AFTER THE PEAK VALUE			MEAN AND STANDARD DEVIATION COMPUTED IN REGION CONSISTING OF ONE SECTION 200 MS LONG AHEAD OF PEAK VALUE ENDING 50 MS BEFORE THE PEAK VALUE			MEAN AND STANDARD DEVIATION COMPUTED IN REGION CONSISTING OF ONE SECTION 100 MS LONG AHEAD OF PEAK VALUE ENDING 50 MS BEFORE THE PEAK VALUE			
	EQ. 1	EQ. 2	EQ. 3	EQ. 1	EQ. 2	EQ. 3	EQ. 1	EQ. 2	EQ. 3	NO NORMALIZATION
WON	0	10	10	9	6	6	7	4	4	
TIED	55*	33	33	23	8	8	17	10	10	1
LOST	0	12	12	23	41	41	31	41	41	11
AVERAGE SIGNAL POSITION IN RANK	2.95	3.25	3.25	2.4	4.72	4.72	6.1	6.68	6.68	12.26

The following columns are a result of selecing echo cycles such that the signal peak is not the largest peak value in the echo cycle

	EQ. 1	EQ. 2	EQ. 3	EQ. 1	EQ. 2	EQ. 3	EQ. 1	EQ. 2	EQ. 3	NO NORMALIZATION
WON	0	3	3	5	4	4	2	1	1	
TIED	15*	5	5	3	1	1	1	1	1	
LOST	0	7	7	7	10	10	12	13	13	
AVERAGE SIGNAL POSITION IN RANK	7.26	8.6	8.6	7.23	9.96	9.96	13.66	15.63	15.63	16.20

*Reference performance to which other results were compared

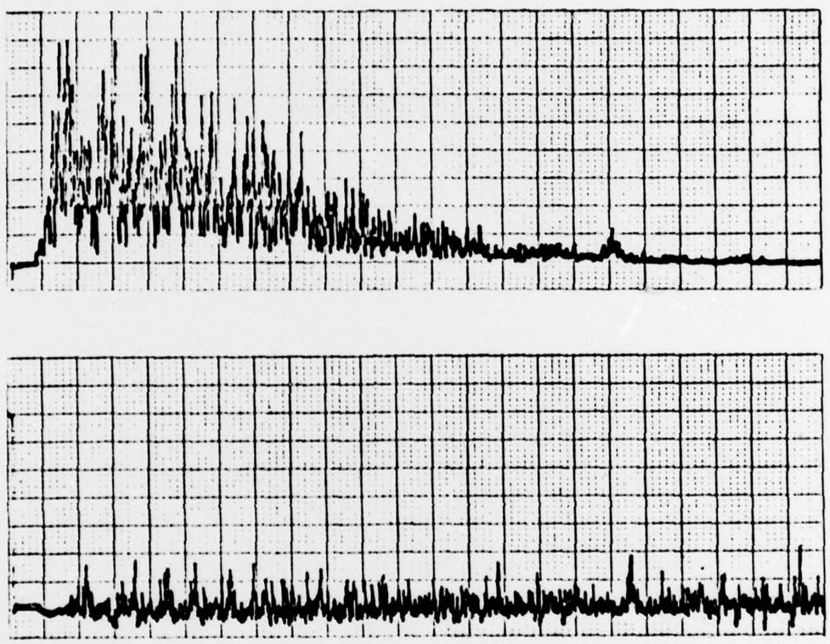

FIG. 4 - THE OUTPUT OF A LINEAR CORRELATOR WITHOUT AGC BEFORE AND AFTER NORMALIZATION

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output of a linear correlator that had input from the beamformer, and the lower graph shows the same output normalized according to Eq. (1). The graphs in Fig. 5 show linear correlator output for input that had been through the AGC. Comparing the un-normalized correlator output shown in the upper graph with the upper graph of Fig. 4 demonstrates that the AGC has partially normalized the output. The further effect of normalization according to Eq. (1) is shown in the lower graph of Fig. 5.

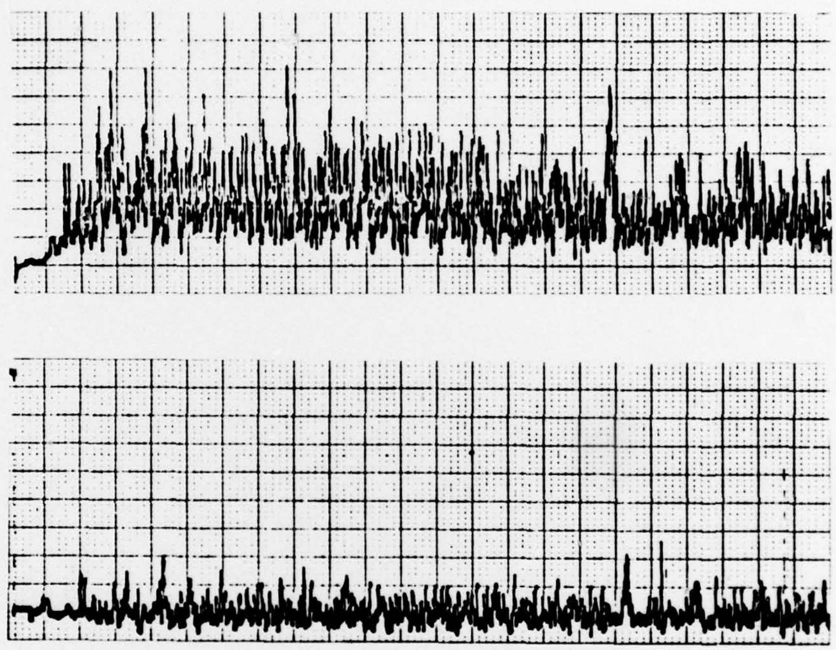

FIG. 5 - THE OUTPUT OF A LINEAR CORRELATOR WITH AGC BEFORE AND AFTER NORMALIZATION

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4. THE GEOMETRIC MEAN AS AN APPROXIMATION TO THE ARITHMETIC MEAN

The next investigation was to determine whether a geometric mean could be used in place of the usual arithmetic mean. The geometric mean, $\overline{G}_m$, is defined by the following equation:

$$\overline{G}_m = \left[\prod_{i=1}^{N} x_i\right]^{\frac{1}{N}}$$

where x_i is the instantaneous value of the interference output and N is the number of samples required to average over a given time interval.

The ratio, K, of the geometric mean to the arithmetic mean,

$$K = \frac{\left[\prod\limits_{i=1}^{N} x_i\right]^{\frac{1}{N}}}{\frac{1}{N}\sum\limits_{i=1}^{N} x_i},$$

was computed for each consecutive 100 ms section of noise. This process was first run with Gaussian noise as the input to the correlator. The mean value of the K's computed in this case was 0.730 and the standard deviation of the K's was 0.097. The experiment was then repeated using a typical sample of sea data as the input to the correlator. For this example, the mean value of the K's computed was 0.668 and the standard deviation was 0.169. If one then expects the value of K to fall within, say, one standard deviation from the mean, this corresponds to an expected fluctuation in the measurements of 2.3 dB for the Gaussian noise and of 4.5 dB for the sea noise.